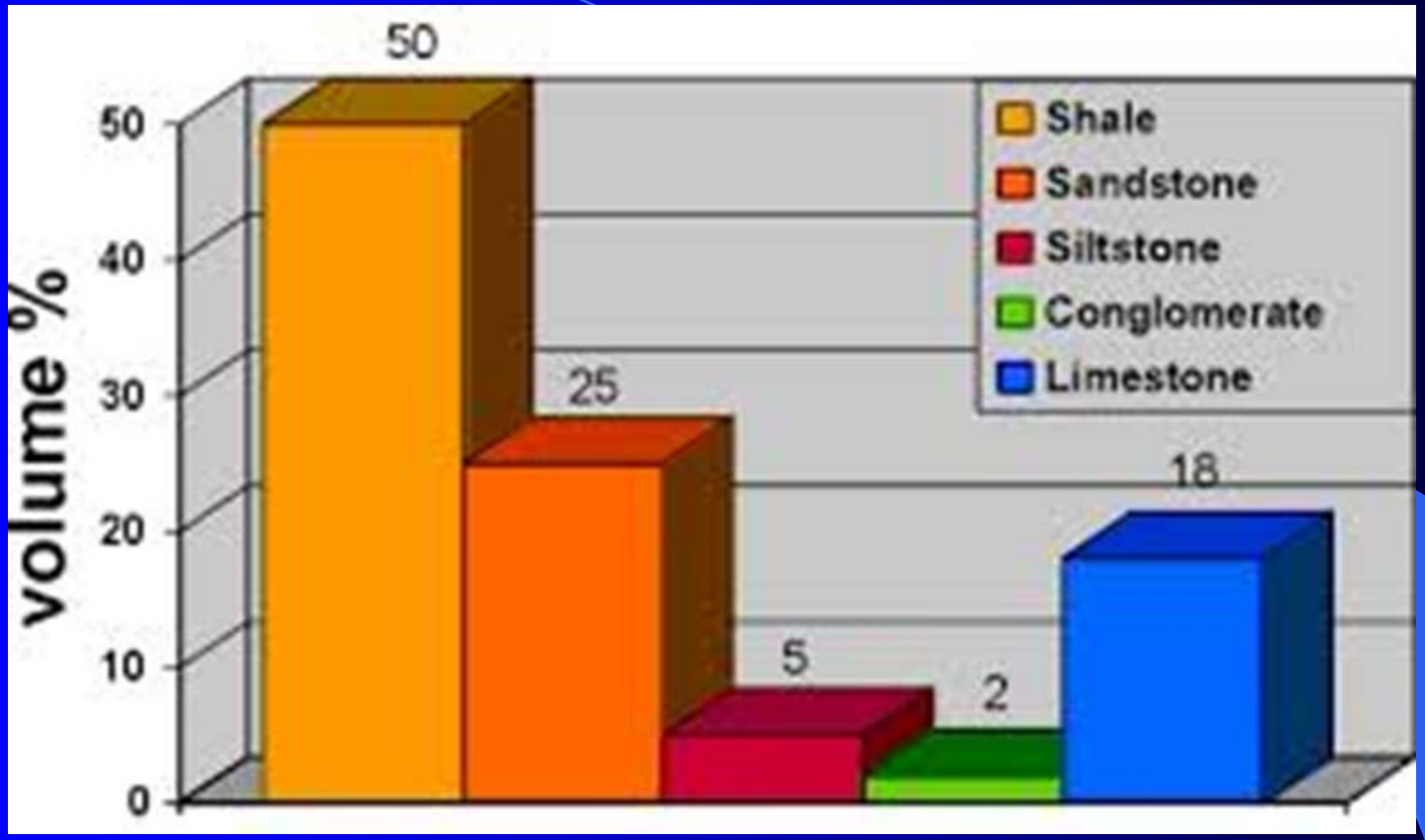
89.325 – Geology for Engineers
Sedimentary Rocks

Siliciclastic sedimentary rocks
- Mudrocks
- Sandstones
- Conglomerates

Biogenic sedimentary rocks
- Carbonates
- Cherts
- Coals

Chemical sedimentary rocks
- Evaporites
- Carbonates
- Phosphorites
- Banded iron formation

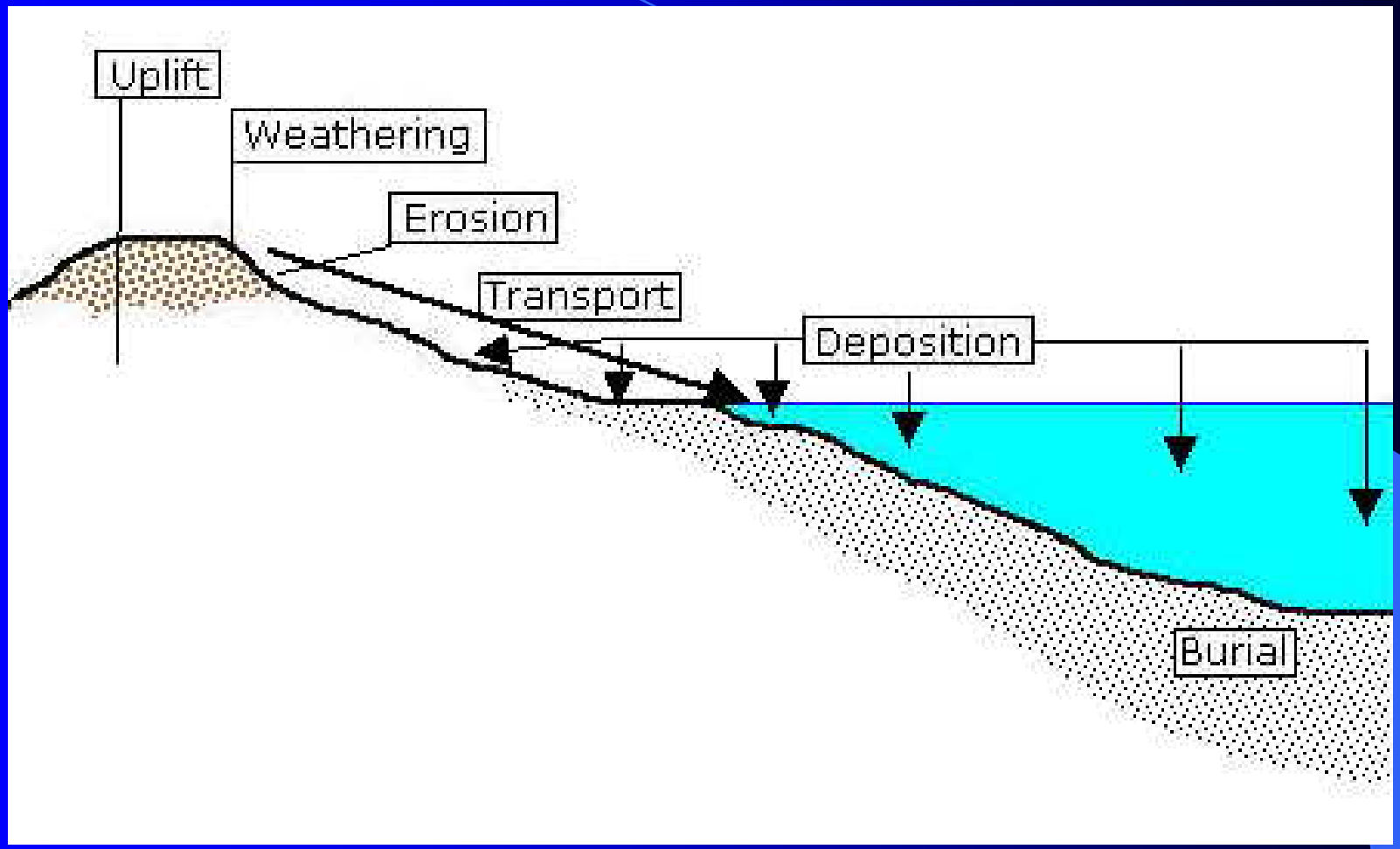
Relative abundance of sedimentary rocks

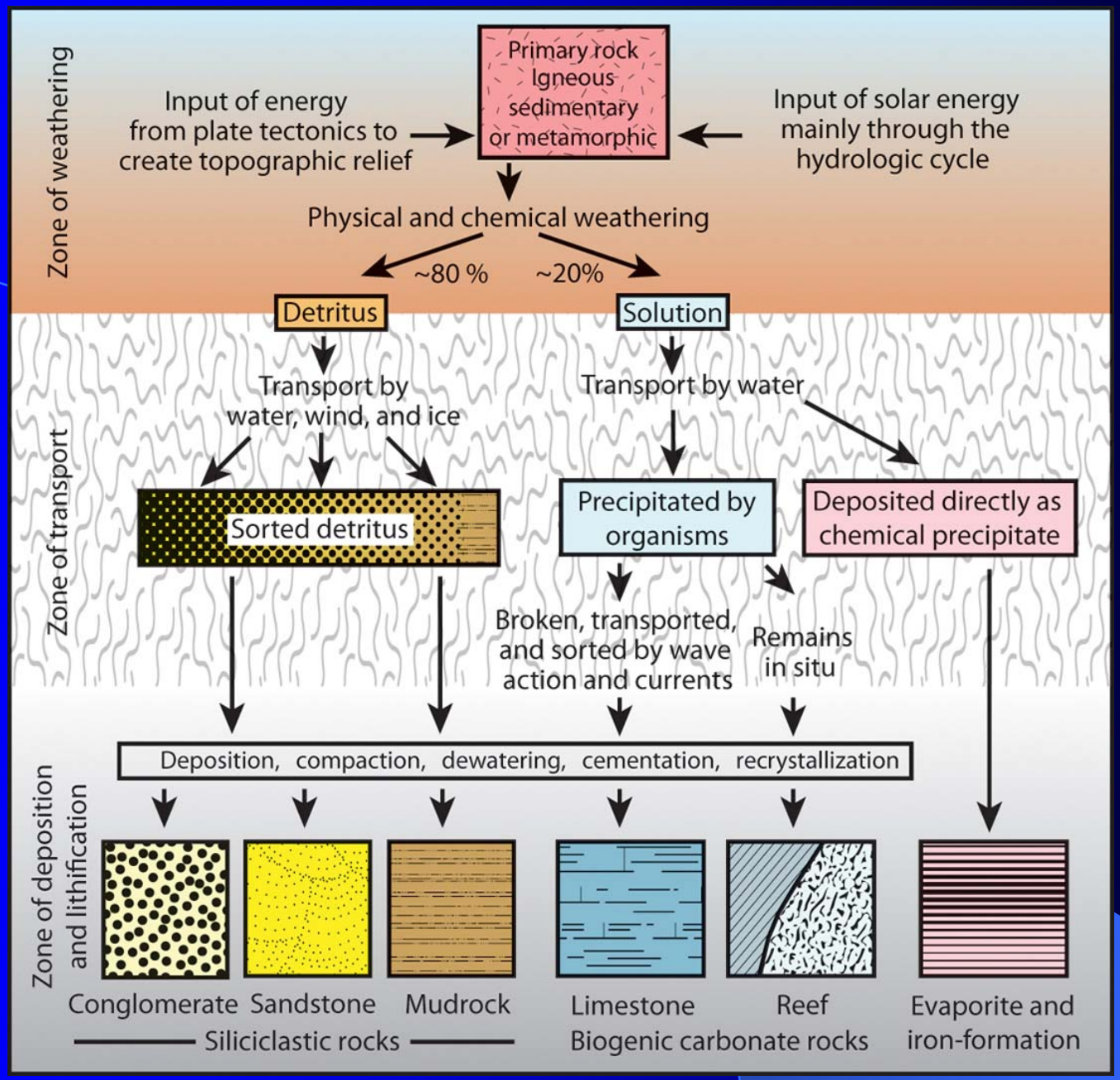


Minerals of Sedimentary Rocks

- Formed by chemical weathering of minerals that are unstable under surface conditions – clay minerals, oxides (hematite, magnetite), hydroxides (goethite, brucite, gibbsite)
- Minerals that precipitate from solution – carbonates, evaporites (halite, sylvite, gypsum), Precambrian iron formation (BIF)
- Detrital minerals – survive physical and chemical weathering processes – e.g. quartz, garnet, rutile, ilmenite, magnetite

Sedimentary processes




Zone of weathering
Primary rock
Igneous
sedimentary
or metamorphic
Input of energy
from plate tectonics to
create topographic relief
Input of solar energy
mainly through the
hydrologic cycle
Physical and chemical weathering
~80 %
~20%
Detritus
Solution
Zone of transport
Transport by
water, wind, and ice
Transport by water
Sorted detritus
Precipitated by
organisms
Deposited directly as
chemical precipitate
Broken, transported,
and sorted by wave
action and currents
Remains
in situ
Deposition, compaction, dewatering, cementation, recrystallization
Zone of deposition
and lithification
Conglomerate
Sandstone
Mudrock
Limestone
Reef
Evaporite and
iron-formation
Siliciclastic rocks
Biogenic carbonate rocks

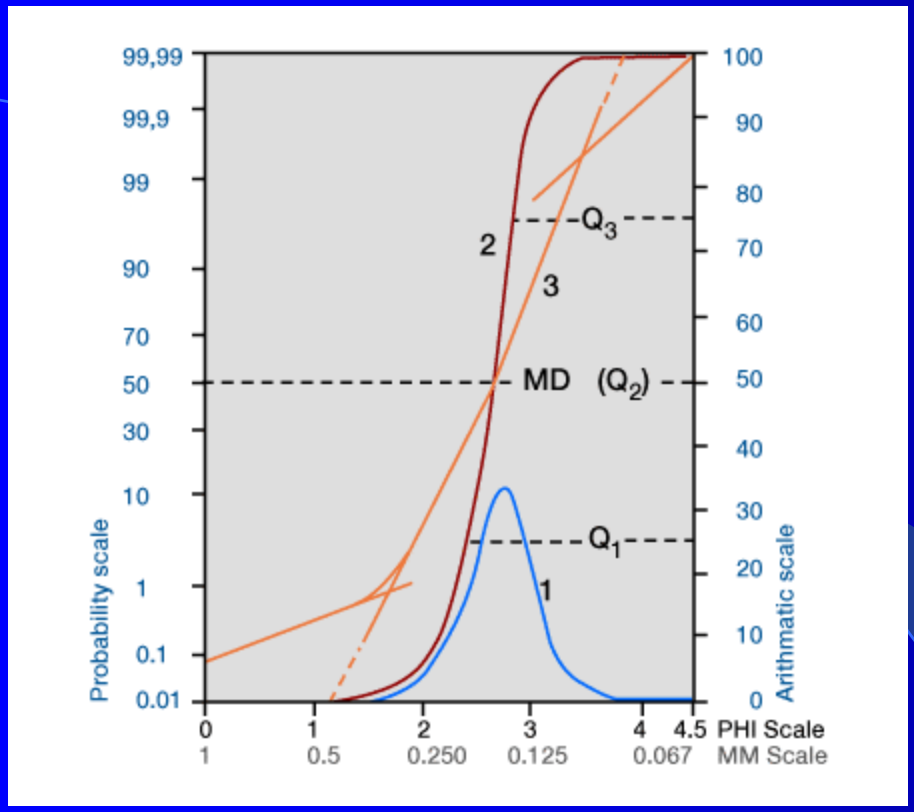
Sediment Size Classification

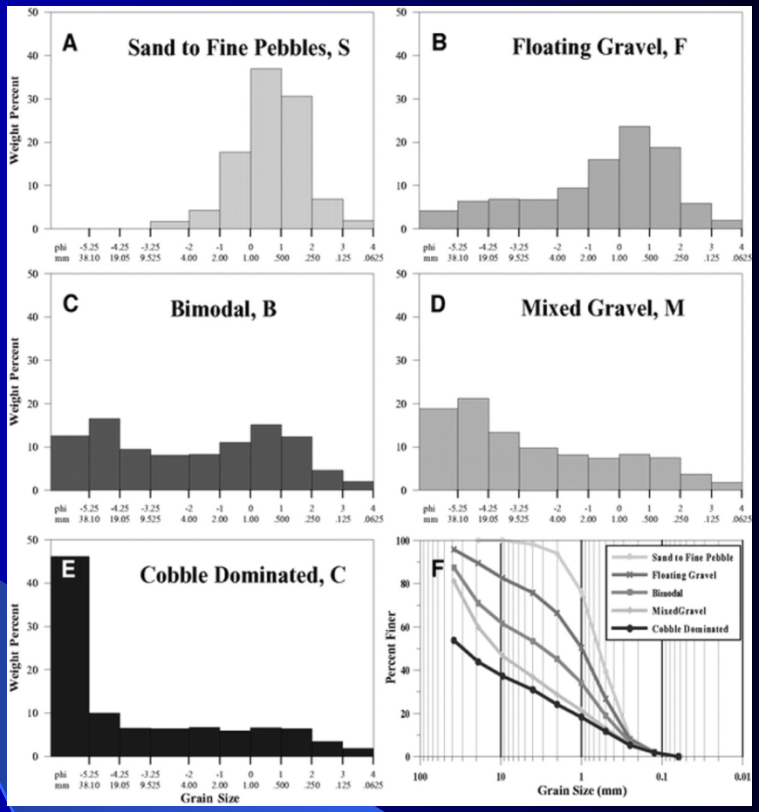
Millimeters (mm)	Micrometers (μm)	Phi (ϕ)	Wentworth size class		Rock type
4096		-12.0	Boulder		
256		-8.0	Cobble	Gravel	Conglomerate/ Breccia
64		-6.0	Pebble		
4		-2.0	Granule		
2.00		-1.0	Very coarse sand		
1.00		0.0	Coarse sand		
1/2 0.50	500	1.0	Medium sand	Sand	Sandstone
1/4 0.25	250	2.0	Fine sand		
1/8 0.125	125	3.0	Very fine sand		
1/16 0.0625	63	4.0	Coarse silt		
1/32 0.031	31	5.0	Medium silt		
1/64 0.0156	15.6	6.0	Fine silt	Silt	Siltstone
1/128 0.0078	7.8	7.0	Very fine silt		
1/256 0.0039	3.9	8.0			
0.00006	0.06	14.0	Clay	Mud	Claystone

$\Phi = -\log_2 D/D_o$

D = diameter of particle D_o = reference diameter (1 mm)

Sediment size distribution is a function of transport and the environment of deposition

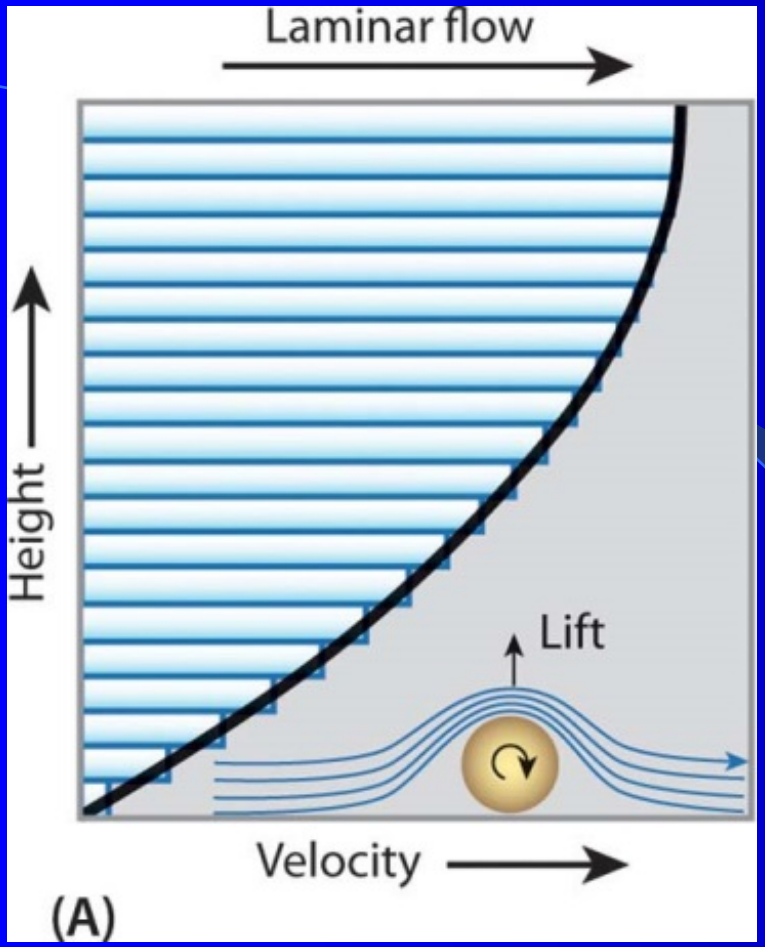


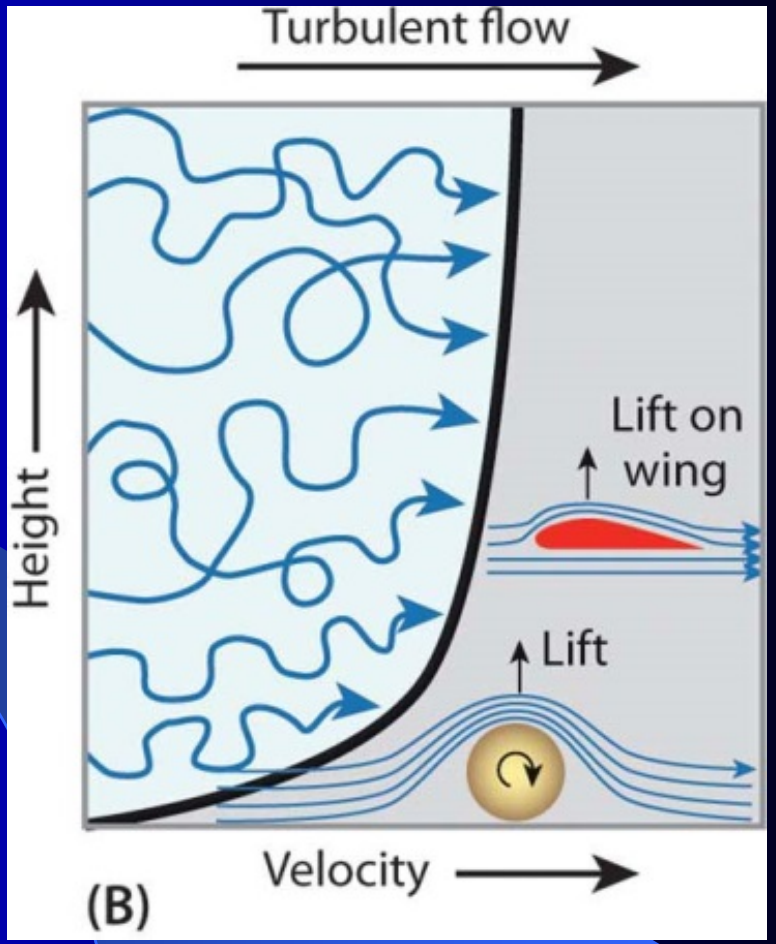


R_e = (4 x hydraulic radius x density x average velocity)/viscosity

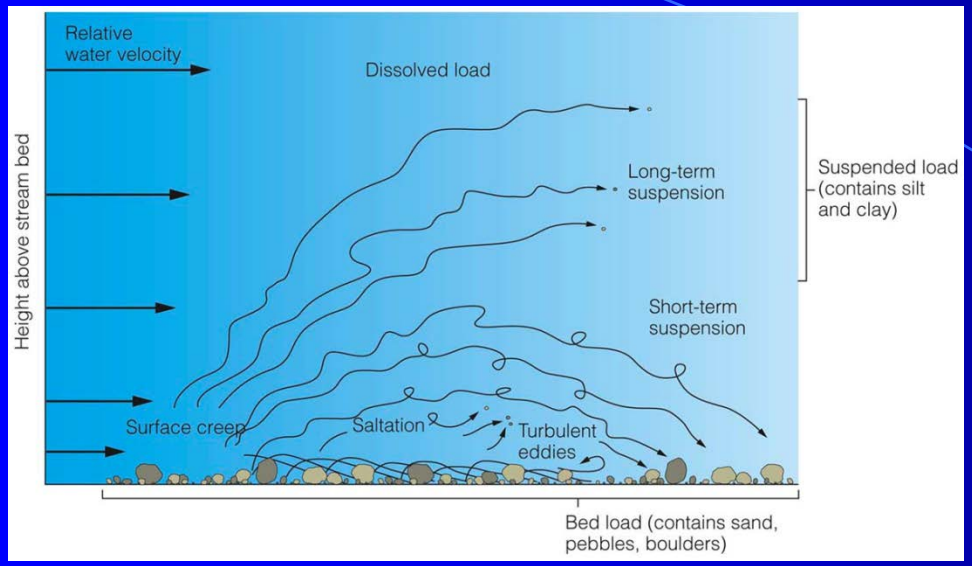
R_e <500 Laminar

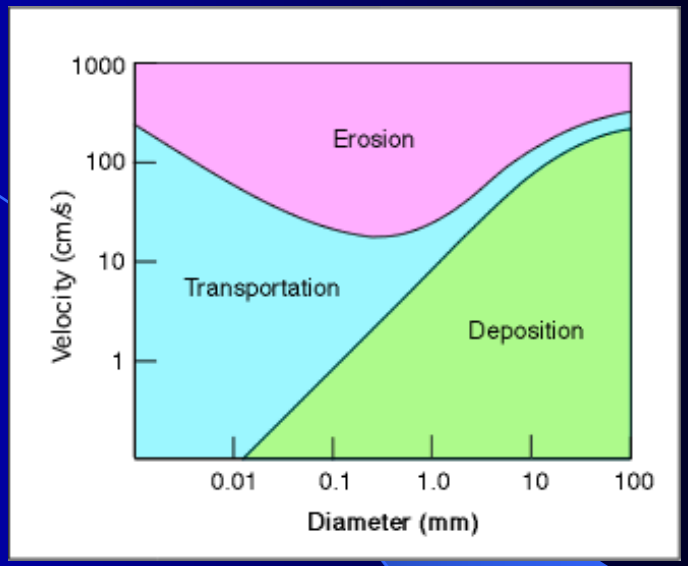
R_e >2000 Turbulent

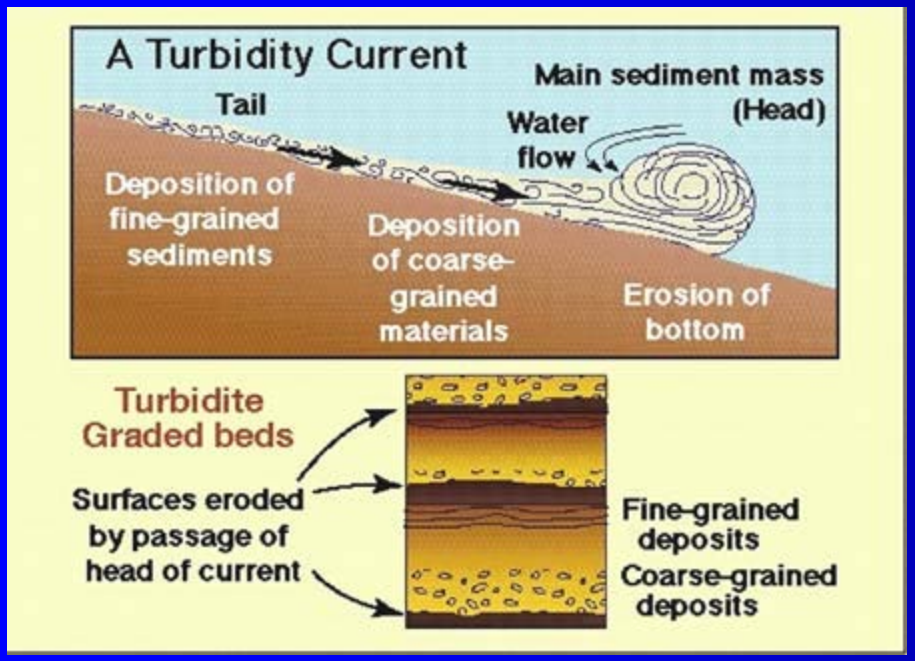


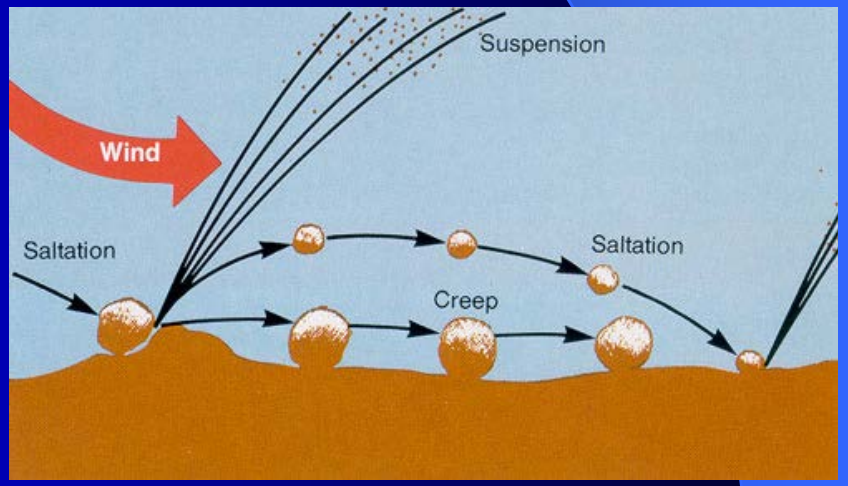


Sediment transport

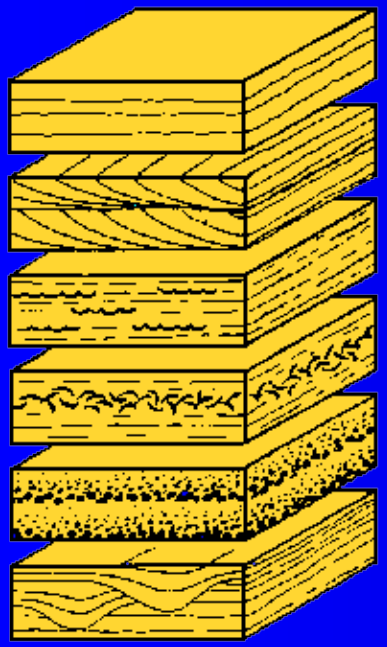








Sedimentary Structures



Planar bedding

Current bedding showing cross-lamination

Ripple marked bedding

Imbricate (overlapping) fossil shells

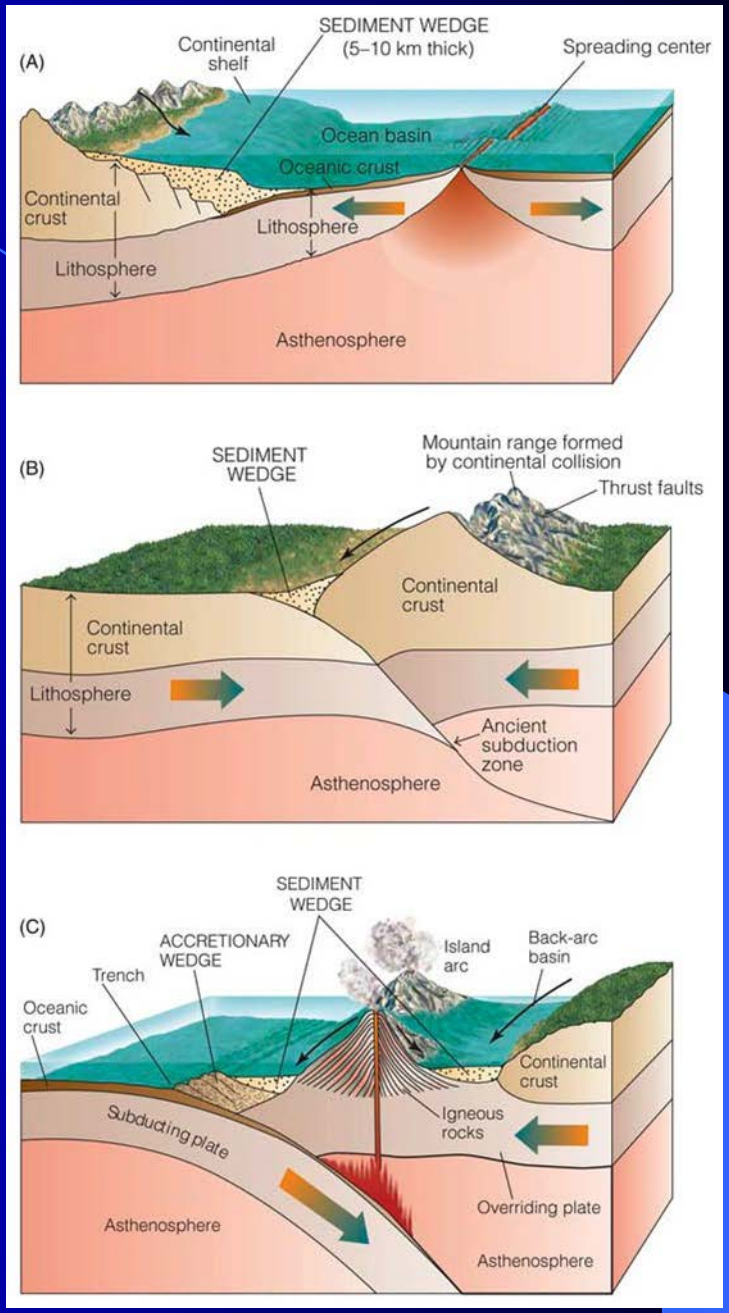
Graded bedding

Cut-and-fill bedding

Clastic Sediments ⟶ Deposition

Locations where clastic sediment is deposited, low-lying areas, are largely controlled by plate tectonics

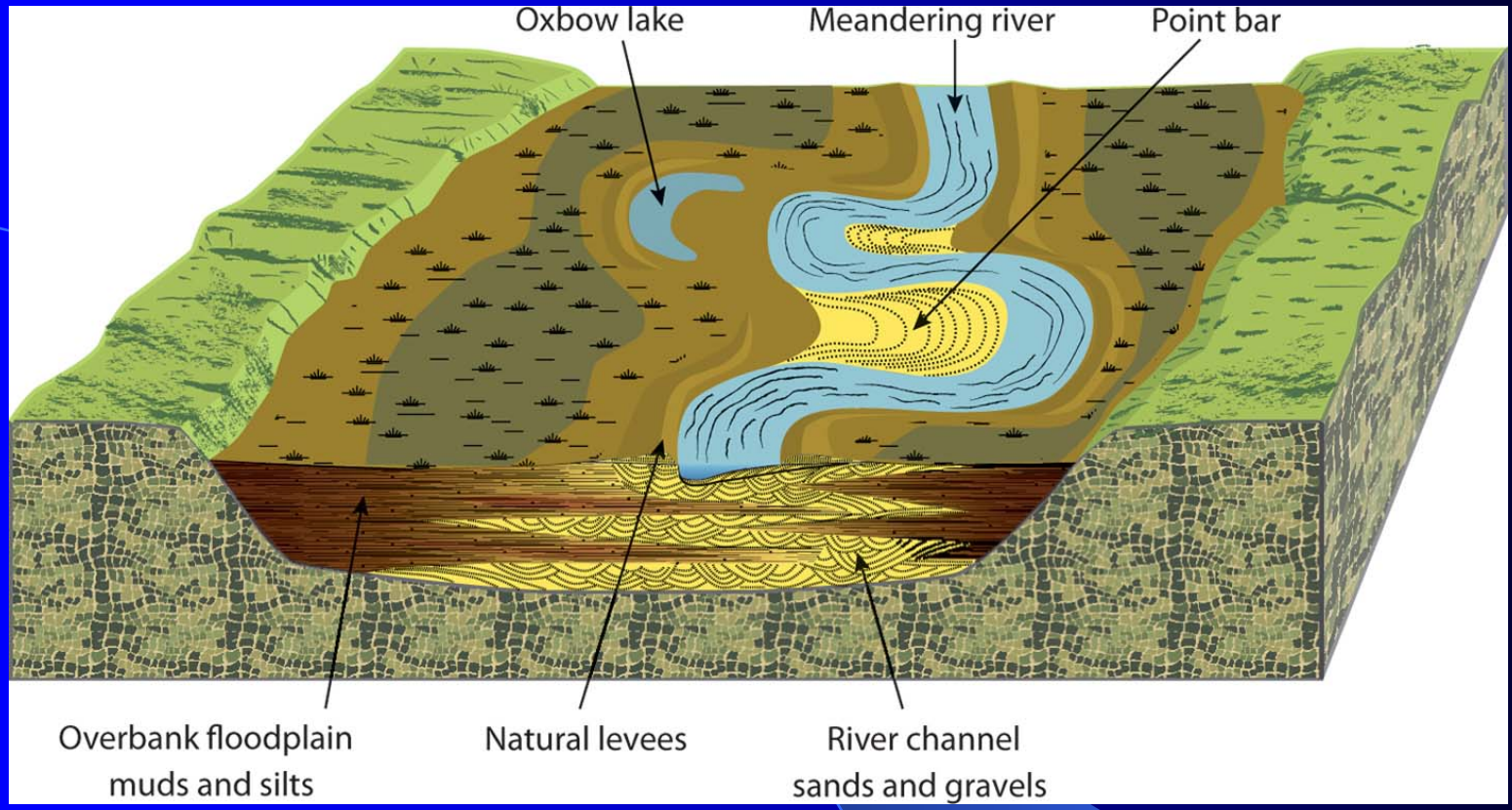
- Troughs
- Rift valleys
- Trenches and accretionary wedges
- Basins

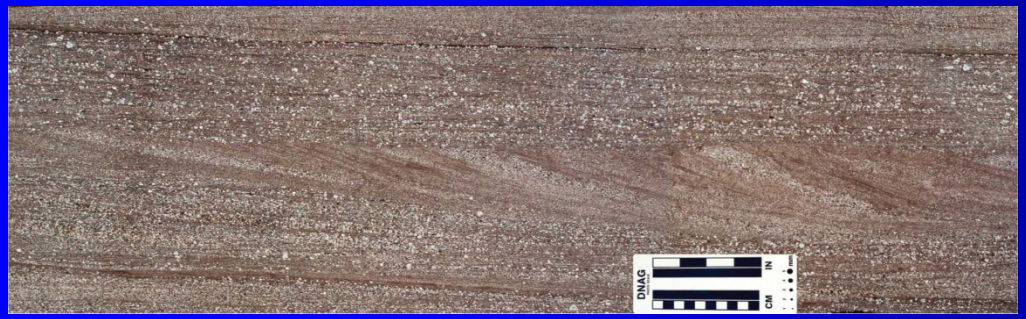


Sedimentary Depositional Environments

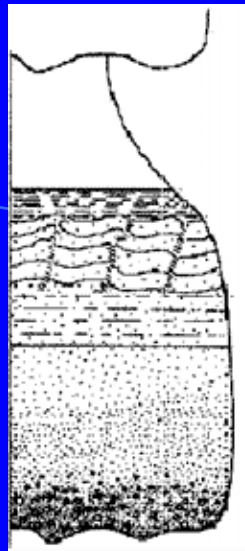
	Depositional Environment	Environmental Characteristics	Organisms	Sediment	Sedimentary Structures	Sedimentary Rocks
non-marine	river channel	variable stream current (high- to low-E), water may dry-up, oxidation	land-freshwater plants & critters	gravel, sand, mud; variable sorting & rounding	crossbeds, ripple marks, graded beds, mudcracks, plant & animal fossil fragments	**conglomerate** **sandstone** **mudstone**
	flood plain	floods (low-E), drying, oxidation, soil formation	land-freshwater plants & critters	mud, sand; well-sorted	bedding, ripple marks, graded beds, mudcracks, abundant fossils	**mudstone (red beds)** **sandstone**
	river delta	stream current, tides low-E	land-freshwater plants & critters	sand, mud; well-sorted	bedding, cross beds, ripple marks, graded beds, abundant fossils	**sandstone** **mudstone**
	alluvial fan	periodic flash floods, mudflows high-E	land plants & critters	gravel > sand; poorly-sorted & angular	plant & animal fossil fragments	**sedimentary breccia** **arkose**
	desert dune	variable wind current (high- to low-E), dry, oxidizing	small insects & reptiles; sparse plants	sand; well-sorted & well-rounded	cross beds, ripple marks, trace fossils	**sandstone**
	playa	low-E, high evaporation, floods periodically, dry	small insects, reptiles; few plants	evaporites, mud	mud cracks, ripple marks, trace fossils	**evaporite** **mudstone**
	lake	low-E, shallow-deep standing water	land-freshwater plants & critters	mud, sand, carbonate sediment	bedding, ripple marks, graded beds, abundant fossils	**mudstone** **sandstone** **limestone**
	glacier	ice, bare rock, cold	sparse plants & critters	gravel; angular & poorly sorted	few	**till**
transitional	beach	waves (high- to low-E), tides, currents, wind	marine & non-marine critters	gravel, sand, mud, carbonate sediment; well-sorted & well-rounded	ripple marks, crossbeds, abundant fossils & fossil fragments	**conglomerate** **samdstone** **mudstone** **limestone & coquina**
	lagoon	low-E, tides, not very oxidized	marine & non-marine plants & critters	mud	bedding, ripple marks, abundant fossils	**mudstone (green-black, not red)**
marine	shallow marine	waves (high- to low-E), tides, strong ocean currents, wind	marine plants & critters	sand, mud, carbonate sediment; well-sorted & well-rounded	bedding, crossbeds, ripple marks, abundant marine fossils	**sandstone** **mudstone** **limestone**
	reef	waves (high- to low-E), tides, strong ocean currents, wind	marine plants & critters	gravel, sand, mud; carbonate sediment; variable sorting	abundant marine fossils	**limestone breccia** **sandstone** **mudstone**
	deep marine	low-E, variable currents	weird marine plants & critters	mud, carbonate & siliceous ooze	abundant marine fossils	**mudstone** **limestone** **chert**

Meandering stream

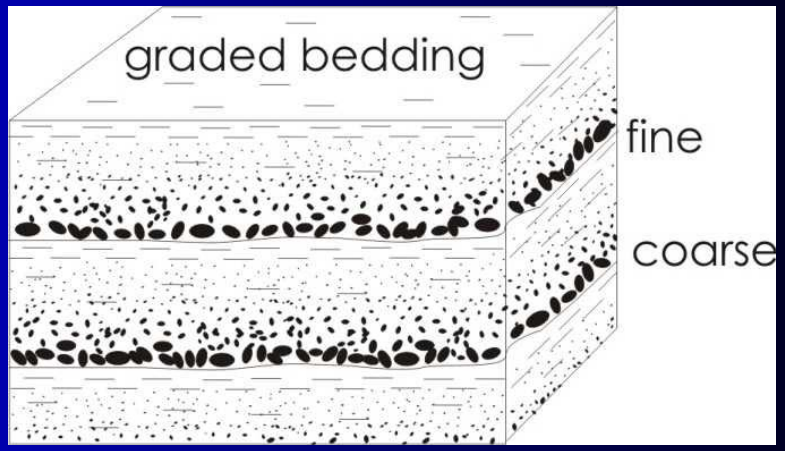




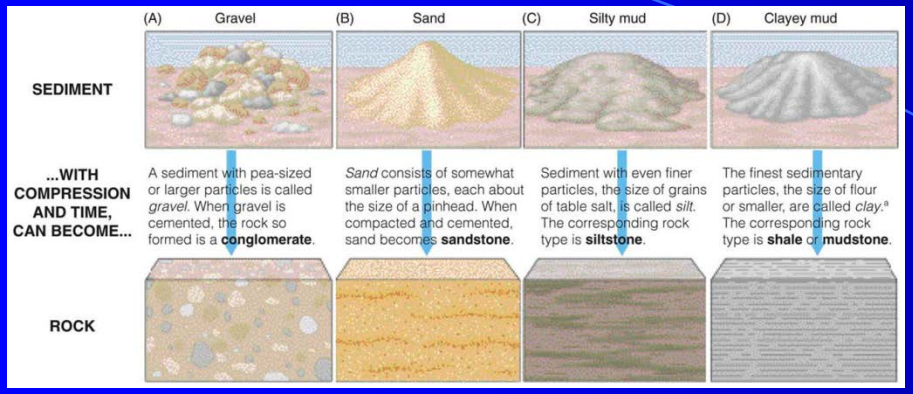
Turbidity Currents



grain size	Bouma divisions	interpretation
mud	pelite	pelagic sedimentation or fine grained, low density turbidity current deposition
silt	upper parallel laminae	?
sand	ripples, wavy or convoluted laminae	lower part of lower flow regime
sand ---> to granule at base	plane parallel laminae	upper flow regime plane bed
	massive, graded	upper flow regime, rapid deposition and quick bed

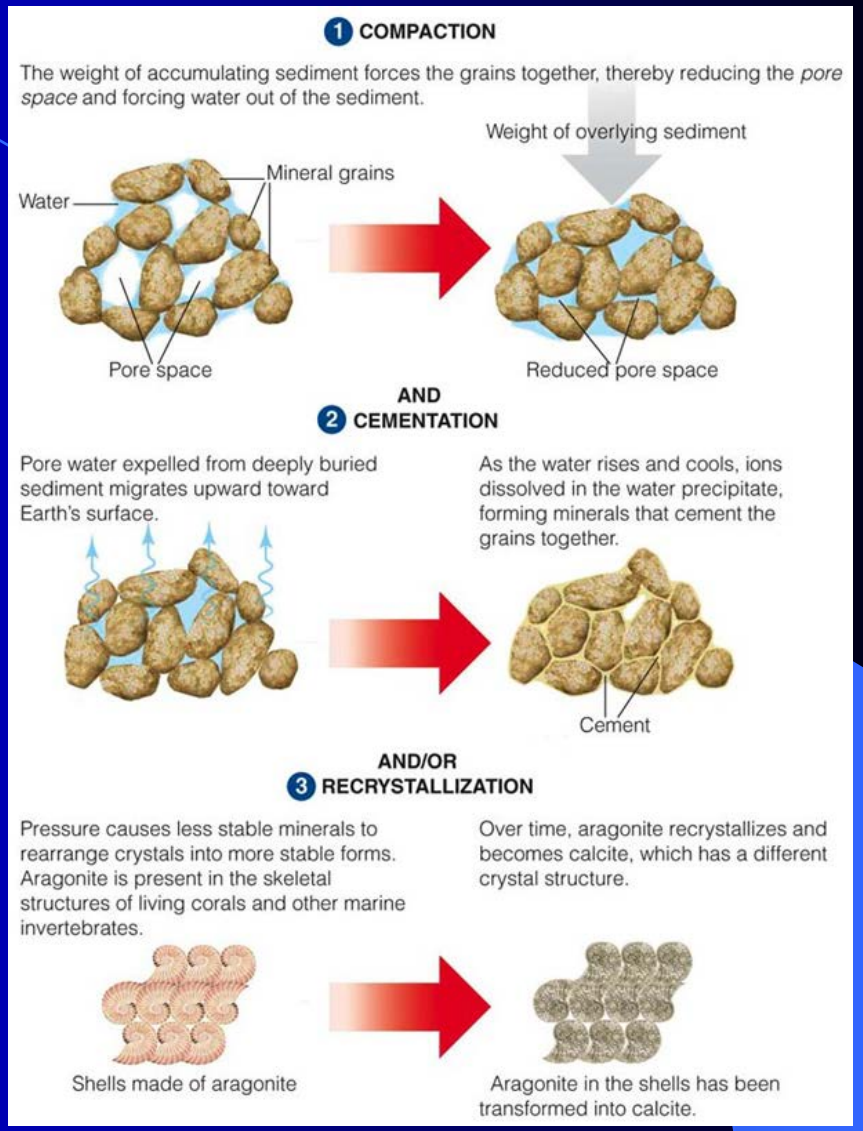


Clastic Sediments → Lithification



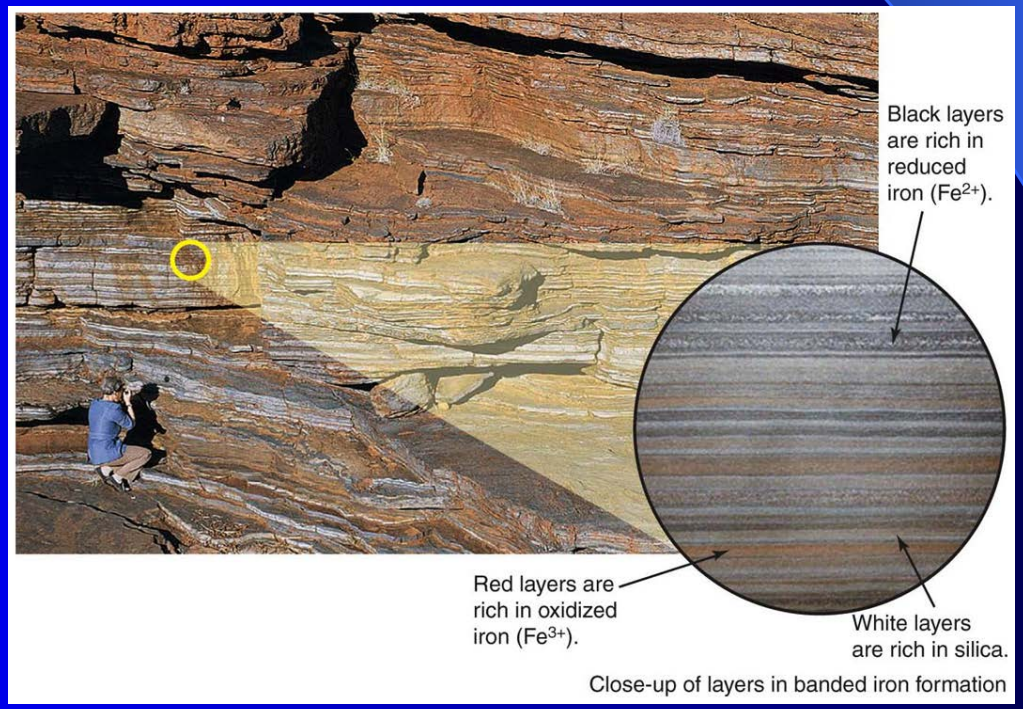
When clastic sediment is lithified, the result is clastic sedimentary rock

- Conglomerate: rounded clasts > 2 mm
- Breccia: angular clasts > 2 mm
- Sandstone: clasts 0.5 - 2 mm
- Siltstone: silt and clay-szied particles
- Shale: mostly clay-sized particles in a rock that easily splits into sheets
- Mudstone: shale that does not split



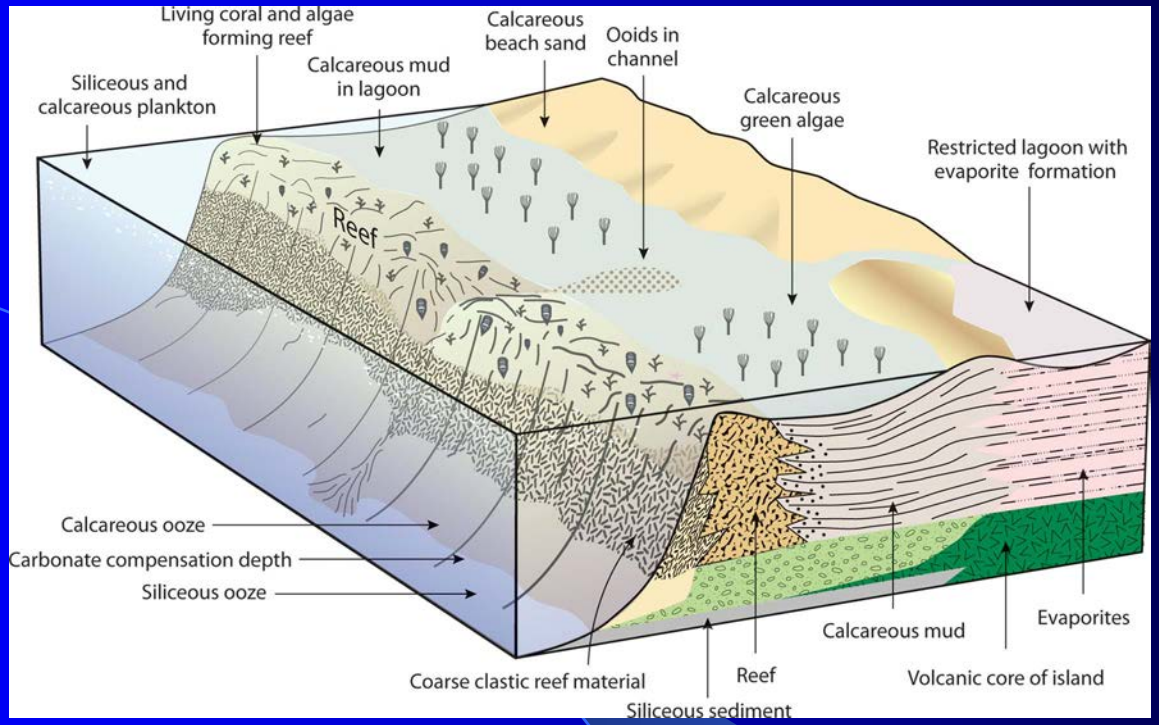
Chemical sedimentary rock results from lithification of chemical sediment formed by precipitation of minerals from water

- Evaporite: formed by evaporation
- Banded iron formation: formed during an atmospheric change from O_2-poor to O_2-rich
- Limestone: lithified shells and other skeletal material from marine organisms
- Chert: tiny particles of quartz from siliceous skeletons of microscopic sea creatures

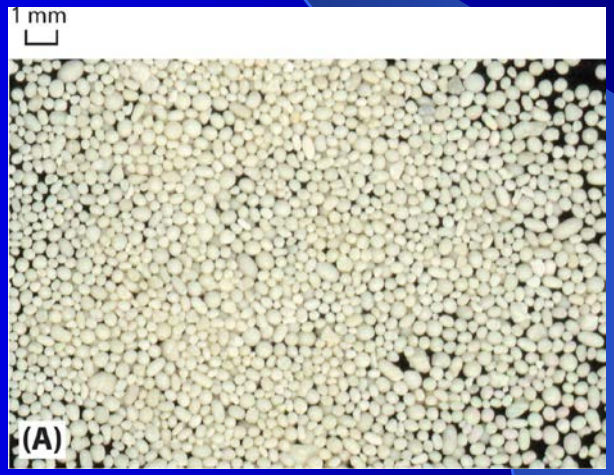


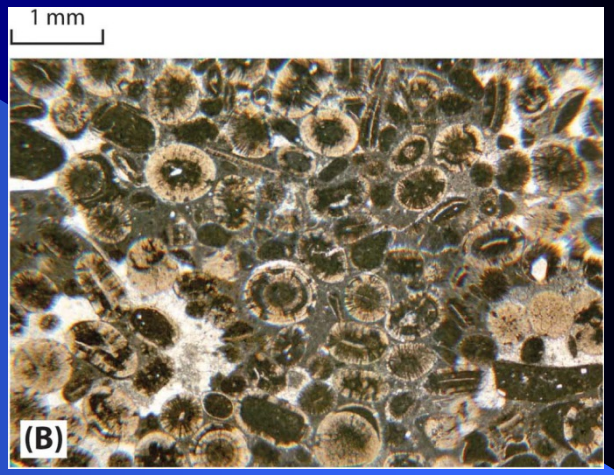
Close-up of layers in banded iron formation

Coral Reefs

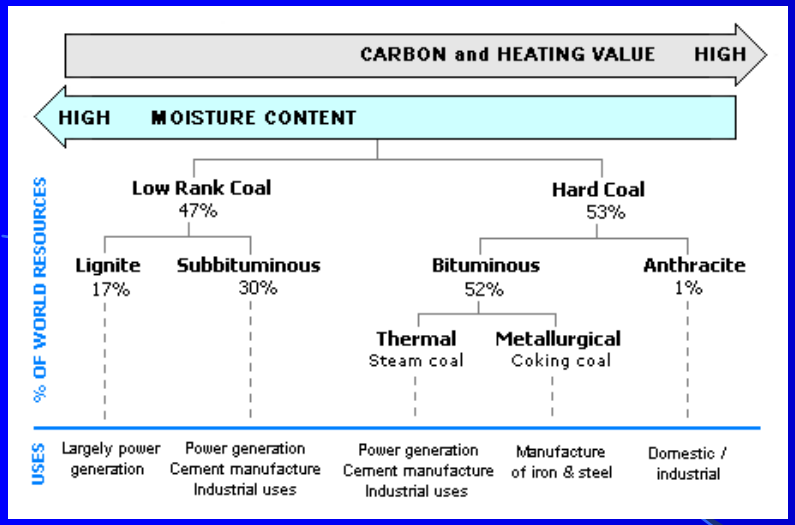

Living coral and algae forming reef
Calcareous beach sand
Ooids in channel
Siliceous and calcareous plankton
Calcareous mud in lagoon
Calcareous green algae
Restricted lagoon with evaporite formation
Reef
Calcareous ooze
Carbonate compensation depth
Siliceous ooze
Calcareous mud
Evaporites
Coarse clastic reef material
Reef
Volcanic core of island
Siliceous sediment

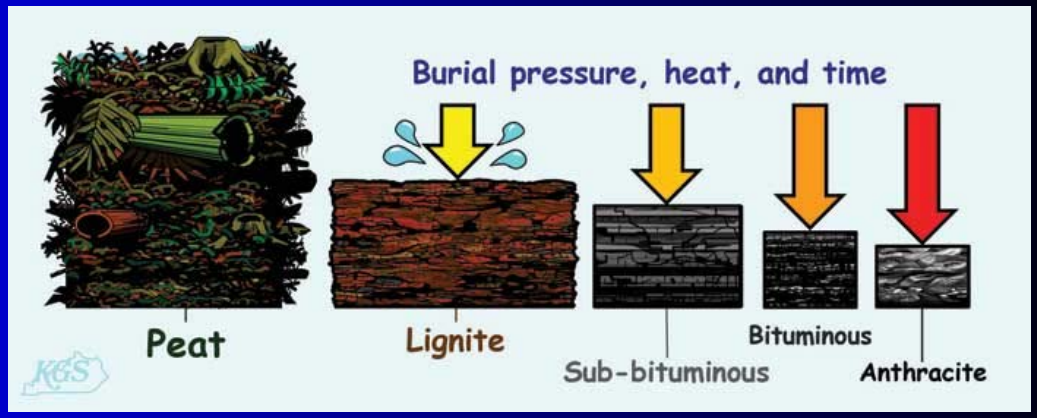

1 cm
Conch shell fragment
Coralline algae
Echinoderm
Holes created by boring organisms
Coral
(A)


1 mm
(A)


1 mm
(B)

Coal





Coal Types and Peat				Total Water Content (%)	Energy Content af* (KJ/kg)	Energy Content (kcal/kg) nar	Volatiles maf** (%)	Vitrinite Reflection in oil (%)
UN - ECE	USA (ASTM)	Germany (DIN)						
Peat	Peat	Torf		75	6,700	1,600		
Ortho-Lignite	Lignite	Weichbraunkohle						
Meta-Lignite	Subbiuminous Coal	Mattbraunkohle		35	16,500	3,950		0.3
Subbitum. Coal		Glanzbraunkohle		25	19,000	4,500		0.45
Bituminous Coal	Hight Volatile Bituminous Coal	Flammkohle	Steinkohle	10	25,000	6,000	45	0.65
		Gasflammkohle					40	0.75
	Medium Vol. Bitumin. Coal	Gaskohle			36,000	8,600	35	1
		Fettkohle		Kokskohle			28	1.2
	Low Vol. Bitumin. Coal	Esskohle					19	1.6
		Magerkohle					14	1.9
Anthracite	Semi-Anthracite	Anthrazit		3	36,000	8,600	10	2.2
	Anthracite							

HARTKOHLE

Formation of Petroleum

- Source rock
- Reservoir rock
- Trap